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Abstract

Some methods by which the applicability of the magnetostrictive delay line readout for wire spark chambers can be extended for use in magnetic field regions are described. For fields up to 20 kG iron-cobalt alloy wires with either a coil or a piezoelectric receive transducer can be used. A different method involving the generation of acoustic pulses in non ferromagnetic wires is described. With a piezoelectric receive transducer this delay line is essentially unaffected by magnetic fields.

Introduction

The magnetostrictive delay line method[1] for digitizing spark coordinates in wire chambers has worked very well for experimental conditions[2] in which the spark chambers were located in essentially magnetic field free regions.

In Fig. 1 we show a schematic view of one gap of a wire chamber that uses a magnetostrictive delay line as the readout. When a spark occurs--due to the passage of a charged particle--between the wires of the upper (high voltage) plane and the lower (ground) plane, the spark current flows along these wires. The magnetic fields of these currents couple to the appropriate magnetostrictive delay line wires placed as shown in the sketch so that one responds to the spark current on the high voltage plane and one to that in the ground plane.

These magnetic field pulses produce a local deformation of the delay line wire and the ensuing acoustic pulse travels along the delay line wire to the receive sensor.

The spark coordinates--x and y in one gap--are obtained by digitizing the time interval between a start signal and the arrival of the pulse at the "receive" sensor. This sensor has usually been a magnetically biased coil in which an output pulse is produced by the inverse magnetostrictive effect, that is, by the change in permeability of the wire due to the strain wave.[3]

The magnetostrictive effect is due in large part to the rotation of the domains in the wire; with the maximum change occurring in the vicinity of the knee of the magnetization curve.[3] Hence the magnitude of the effect is dependent on the average flux density in the wire and tends to decrease with a magnetic saturation of the wire. Similarly, the inverse effect has a maximum for a given bias and drops off with increasing (or decreasing) field.

In this paper we report on some measurements and technical modifications that we have done by which the effect of an external magnetic field is minimized. Lastly we describe below a different method which is non-magnetic in nature and hence magnetic field independent.

Ferromagnetic Alloys in Magnetic Fields

In experimental situations in which the spark chambers need to be placed in a magnetic field, the "send" end of the readout delay line is, by necessity, exposed to the full magnetic field, whereas often the "receive" transducer can be placed in a weaker field region outside the magnet by extending the length of the wire line.

In order to simulate the response of the "send" end in the above-mentioned experimental situation, we measured the response of some ferromagnetic alloys in the arrangement shown in Fig. 2a. The "receive" transducer was located at least ten feet away from the magnet where the magnetic field was less than 50 gauss. The spark chamber signals were simulated by discharging a condenser through a 2-turn coil which produced pulsed magnetic fields comparable in amplitude and duration to those from the usual spark currents.

Measurements were done for wire orientations around 90 deg, at which angle the induced field in the wire is expected to be minimal. Furthermore, as shown in Fig. 2b, such an orientation is satisfactory for reading out wire planes in which the wires are oriented at any convenient angle less than 90 deg to the field direction.

In Figs. 3 and 4, we show the amplitude of the signal as a function of magnetic field for an iron-cobalt alloy ribbon with approximate composition: 49% iron, 49% cobalt, 2% vanadium.[4]

For wire orientations $\theta < 90$ deg the signal drops off monotonically to about 10% of its zero field value, with the drop off rate being slowest for angles close to 90 deg, as would be expected. From 10 kG onwards, at which fields the alloy would be expected to be close to saturation, the signal amplitude continues to drop off, but with a smaller slope, reaching limiting values of 3 to 5% of the zero field signal at 20 kG (which is the highest field obtainable in our test magnet).

For orientations $\theta > 90$ deg in which the dc component of field from the magnet along the wire and the pulse field from the coil have opposite directions, the polarity of the output signal reverses itself in going from 2 kG to 4kG. In this transitional region the shape of the output signals is very poor and unsuitable for spark chamber readout use. However, at higher fields the signals continue to be very clean and narrow up to the maximum measured value.

Figure 5 shows similar measurements on nickel wire which show a more rapid drop off with field as would be expected from the lower saturation value (≈ 6 kG), although at 135 deg one can see a usable signal at high fields.

This lower slope at high fields is probably due to a combination of domain rotation in the saturation region and to the strain induced in any magnetic material by a pulsed magnetic field.[5]

The amplitude and strength of the magnetostrictive pulses in the high field region are quite adequate for readout use since the background noise, which is mainly due to the amplifier stage, is an order of magnitude smaller.

"Receive" Transducers for Use in Magnetic Fields

The "receive" transducers we have previously used consisted of 200-turn coils biassed by a small Alnico magnet placed in close proximity to the coil. This arrangement turned out to be fairly sensitive to external magnetic fields. A more satisfactory arrangement in this respect is shown in Fig. 6. The coil has the same dimensions as before, i.e., 200 turns of No. 50 wire wound on a lucite form in which the dimensions of the windings were 0.060 in. outside diameter and 0.020 in. in axial length. The bias magnet is a concentric cylinder of Plastiform[6] magnet with dimensions 1/4-in. in length, O. D. = 0.250 in. and I. D. = 0.125 in., surrounded by a soft iron concentric cylinder which serves as a magnetic shield. This arrangement provided a bias field of 300 gauss in the center which is adequate for the iron-cobalt wire. The shielding is satisfactory for magnetic fields up to 2 kG, above which the signal amplitude drops off rapidly.

Figure 7 shows the shape of the output pulse obtained from the coil directly and the clipped output from the integrated circuit amplifier, which has a gain of 150.[7]

A more efficient transducer can be made for the "receive" pulse by using a piezoelectric disc to sense the strain wave. For this purpose we used a disc of PZT-5, a lead-zirconium-titanate ceramic[8] with diameter = 0.125 in. and thickness = 0.050 in. mounted as shown in Fig. 8.

The amplitudes and shapes of the acoustic pulses from the wire are shown in Fig. 7 at the input and at the output ends of the clipped amplifier in which the gain was decreased by a factor of five in order to operate it in a linear region.

Although the piezoelectric transducer produces larger amplitude signals than the coil transducer, the acoustic mismatch produces background reflections and broadens the output pulse. Its main advantage for our purposes is that it is completely insensitive to magnetic fields.

Spark-Induced Acoustic Pulse Generation

In the course of trying to find some means of generating acoustic waves electrostatically in some non-ferromagnetic wire, we noticed (accidentally) that if a high voltage electrode was allowed to spark to the test wire, an acoustic pulse was produced, similar in shape to the magnetostrictively generated pulses.

This effect, which can be attributed to the impact on the wire surface of the shock wave produced by the heating of gas in the immediate vicinity of the spark, is well known. For instance, in thin aluminum plate spark chambers the sparks produce small indentations and occasionally small holes.

The shape of the acoustic pulse is improved by channeling the spark discharge as shown in Fig. 9(a). The "groove" in which the transducer wire is placed is made of metal (aluminum) with epoxy glass insulating flanges. The aluminum backing and the wire are both grounded so that the spark current can flow through them (mostly through the aluminum backing since the inductance of the wire to ground is appreciable). The method of coupling such a wire transducer to a wire spark chamber plane is shown in Fig. 9(b).

Figure 10 shows the shape of the output pulse produced in such an arrangement and using the PZT-5 piezoelectric transducer. The wire is Nichrome 0.015 in. in diameter. The output pulse amplitude is not very sensitive to the electrode spacing. It is a factor of 10 higher than the comparable magnetostrictively generated pulses, although with the disadvantage that it is wider.

Such an arrangement is essentially unaffected by the presence of magnetic fields both on the "send" and "receive" sides.

Acknowledgements

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References

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   Alternative methods have been proposed by: G. Gianelli, Proc. Informal Meeting on Film-less Spark Chamber Techniques and Associated Computer Use, CERN 1964, p. 325; D. Maeder,

Helv. Phys. Acta 38, 343 (1965).

2. T. Devlin, T. Droege, J. Solomon, V. Perez-Mendez, Bull. Am. Phys. Soc. 11, 38 (1966).
3. R. M. Bozorth, Ferromagnetism (Van Nostrand, Princeton, N. J., 1951).
4. Samples of this wire were obtained from: Wilbur B. Driver Co., Newark 4, N. J. and Vacuumschmelze Aktiengesellschaft, Hanau, West Germany. We would like to thank Dr. G. Gianelli (Bari) and Dr. J. Brautti (CERN) for bringing the latter source of supply to our attention.
5. W. F. Brown, Micromagnetics (Interscience Publishers, New York, 1963).
6. Manufactured by Leyman Corp., Magnetic Division, Cincinnati 38, Ohio.
7. See following paper. Also, F. A. Kirsten, V. Perez-Mendez and J. M. Pfab, UCID-2629, Lawrence Radiation Laboratory (August 1965) (unpublished).
8. Manufactured by Clevite Corp., Piezoelectric Division, Bedford, Ohio.

Figure Captions

Fig. 1. Schematic view of one gap of a wire chamber with wire grids at 90 deg to each other and showing the magnetostrictive readout lines on the high voltage and ground planes.

Fig. 2. (a) Magnet arrangement used for measuring effect of H field on ferromagnetic alloys.
(b) Schematic arrangement to show that readout line at 90 deg to H field can be used for various wire plane orientations.

Fig. 3. Amplitude of signal from 50-50 Fe-Co alloy wire vs. H field. $\theta_{wire} < 90$ deg.

Fig. 4. Amplitude of signal from 50-50 Fe-Co alloy wire vs. H field. $\theta_{wire} > 90$ deg.

Fig. 5. Amplitude of signal from nickel wire vs. H field.

Fig. 6. Photograph of receive transducer showing (a) amplifier card, (b) wire, (c) iron shield, (d) Plastiform magnet, (e) coil in Al shield, (f) damping rubber pad.

Fig. 7. Output pulse from coil and piezoelectric "receive" transducers at amplifier input and output.

Fig. 8. Piezoelectric disc "receive" transducer showing mounting of disc on lead damper.

Fig. 9. (a) Mounting arrangement showing channeling of spark.
(b) Method of coupling spark discharge transducer to wire plane.

Fig. 10. Shape and amplitude of output pulse produced by spark discharge on Nichrome at input and output of amplifier. Amplifier has unit gain with clipping action.

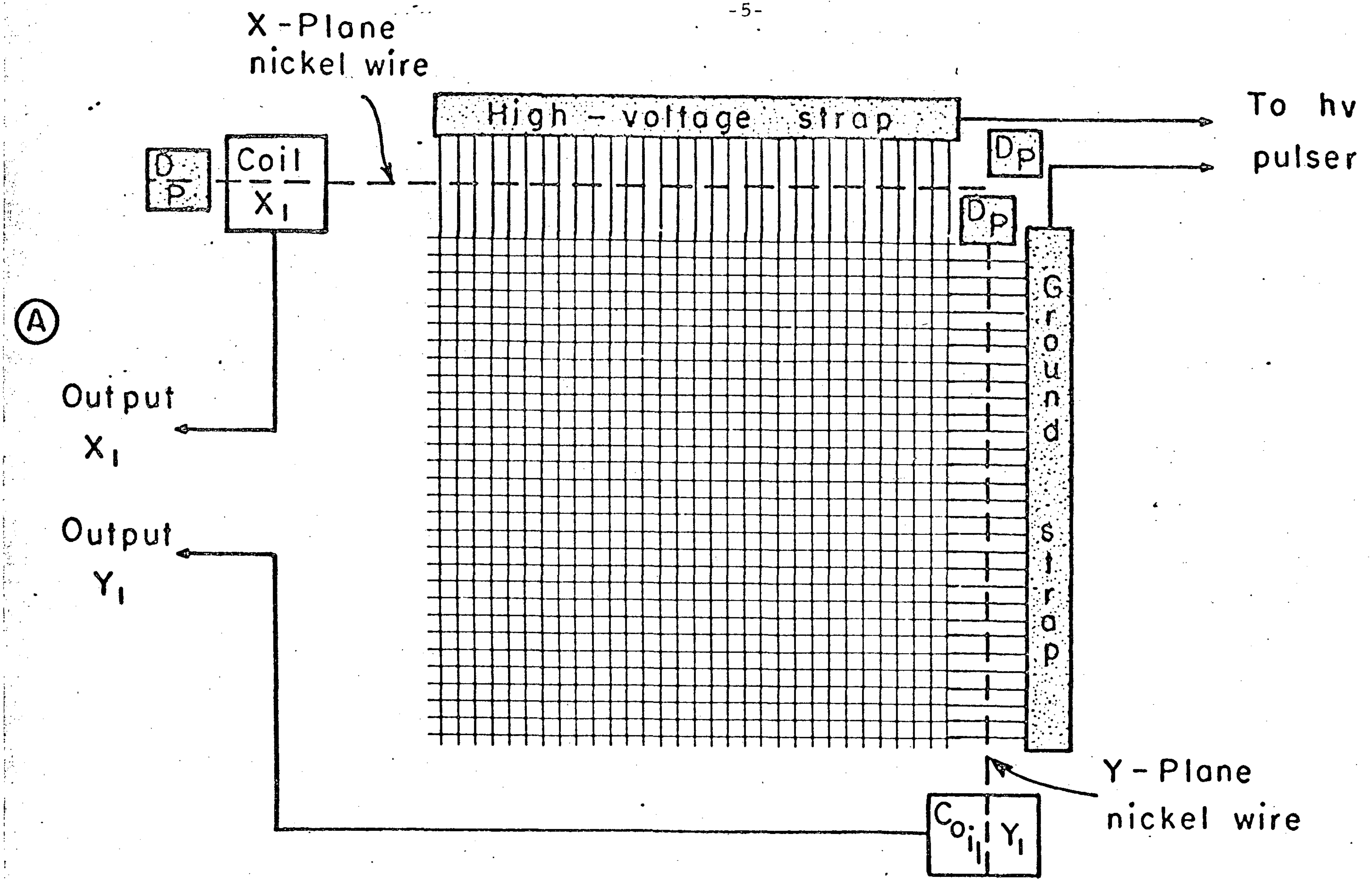
X-Plane nickel wire
High - voltage strap
To hv pulser
D/P
Coil/X1
Dp
Dp
A
Output X1
Output Y1
Ground strap
Y-Plane nickel wire
Coil Y1

FIG. 1

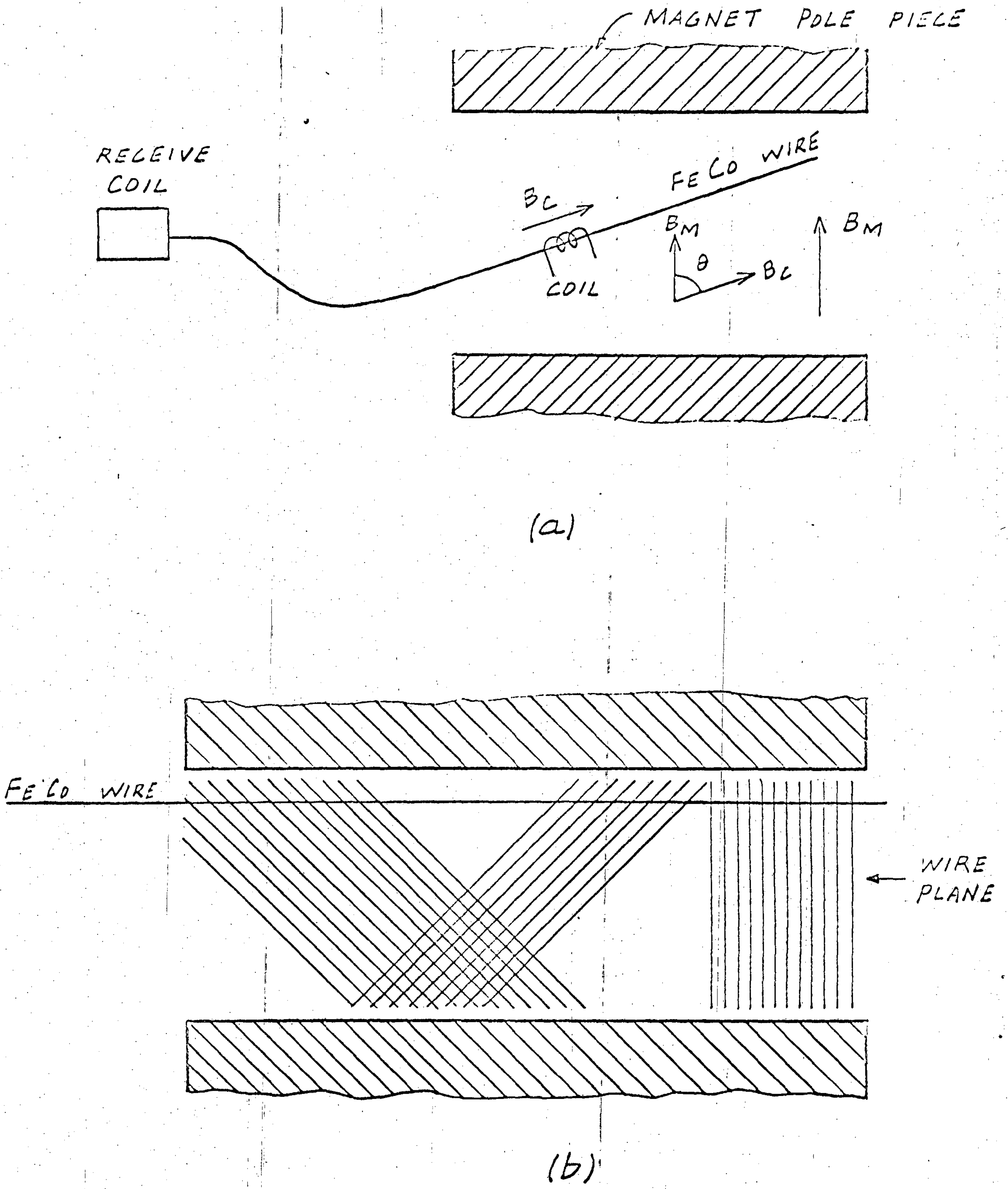
MAGNET POLE PIECE
RECEIVE COIL
FE CO WIRE
B_C
COIL
B_M
θ
B_C
B_M
(a)
FE CO WIRE
WIRE PLANE
(b)

Fig. 2

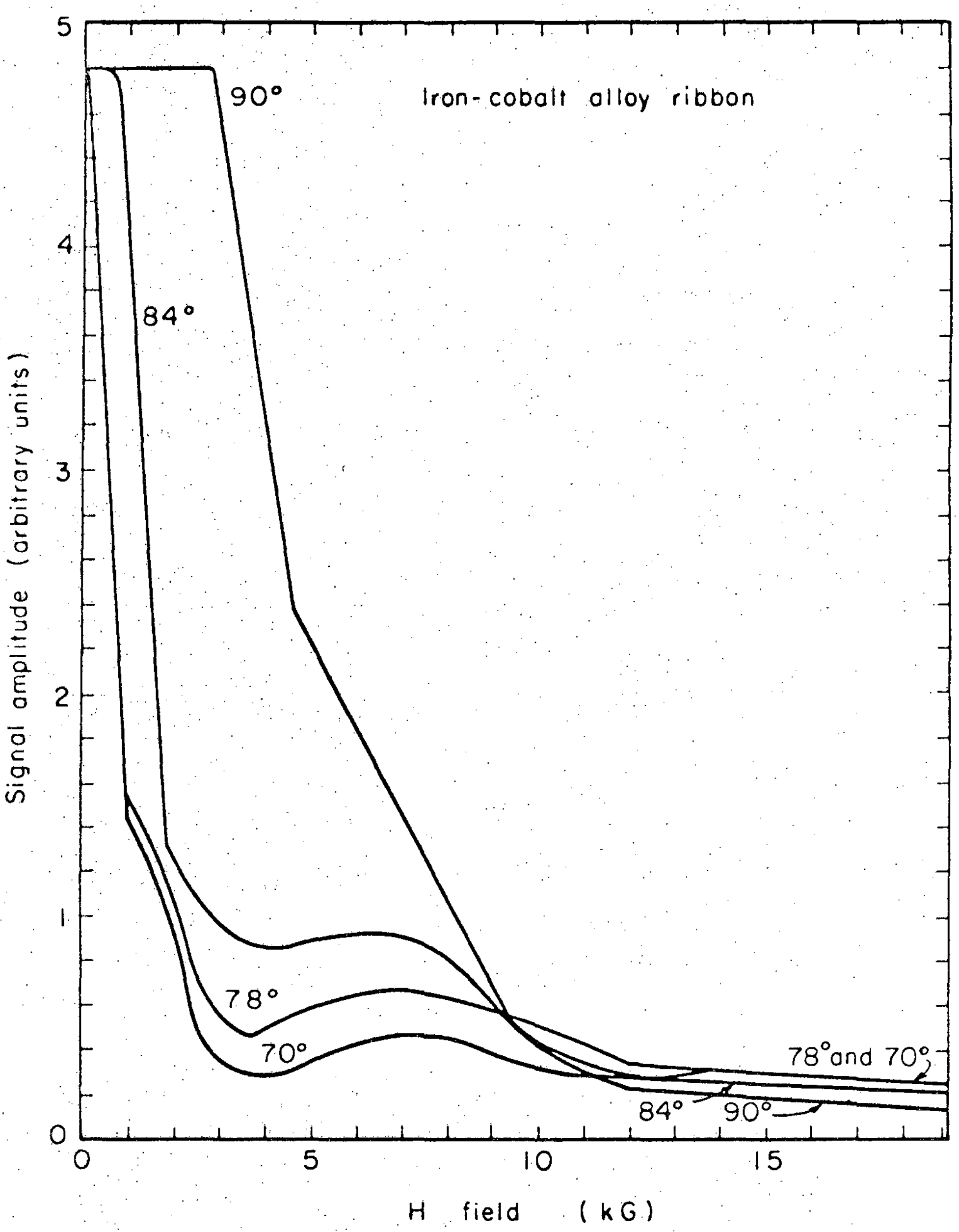

Fig. 3

MUB-9651

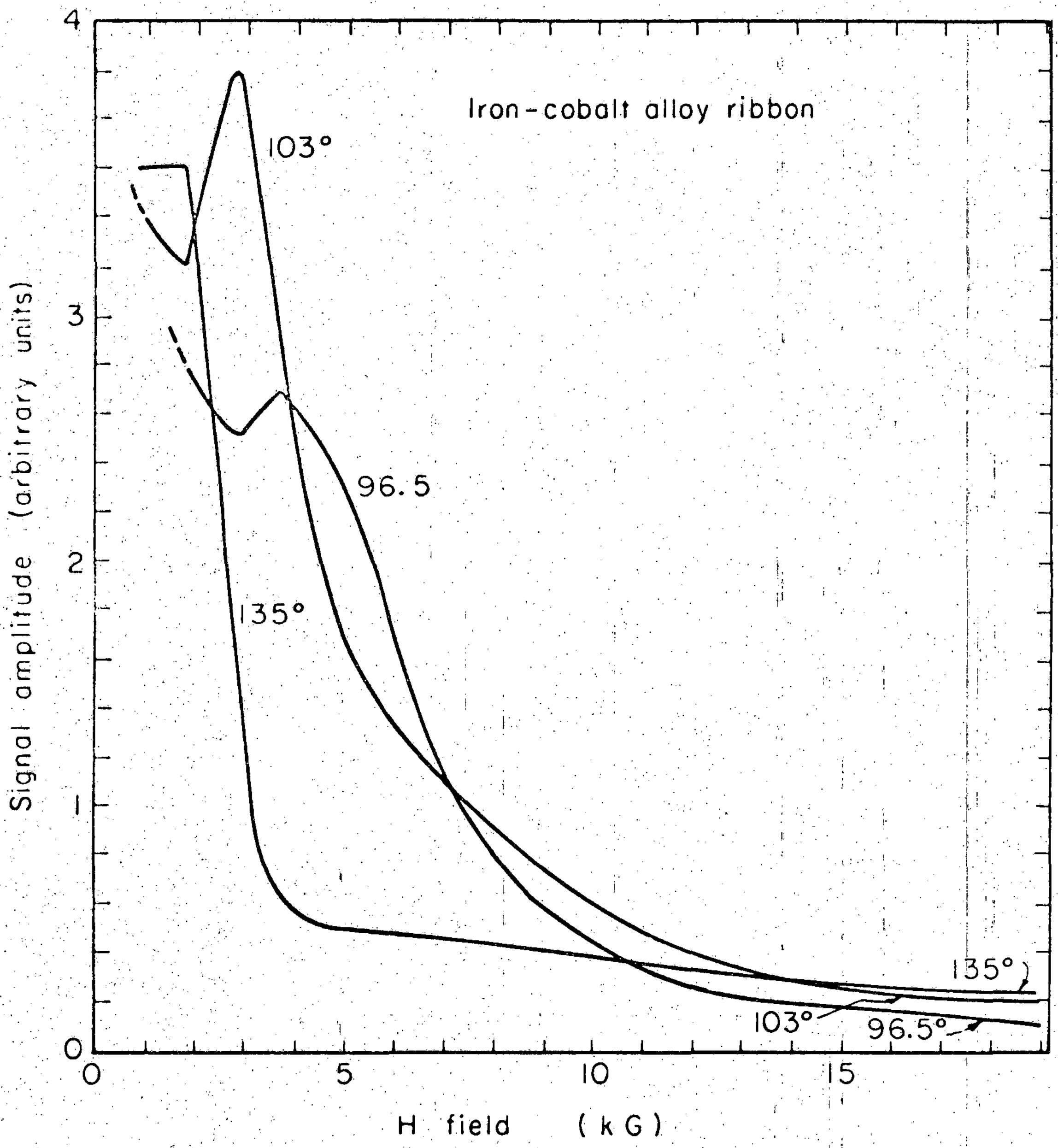

Fig. 4

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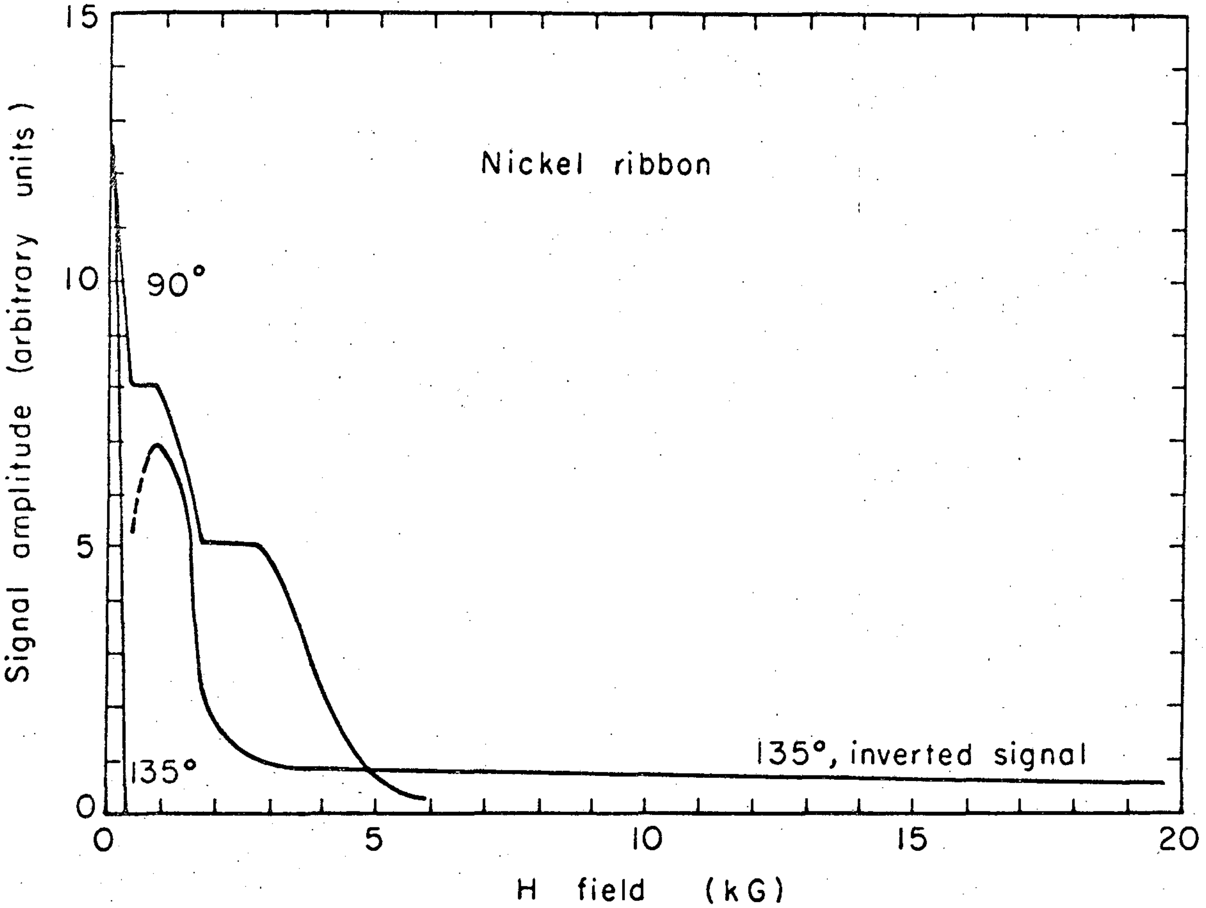
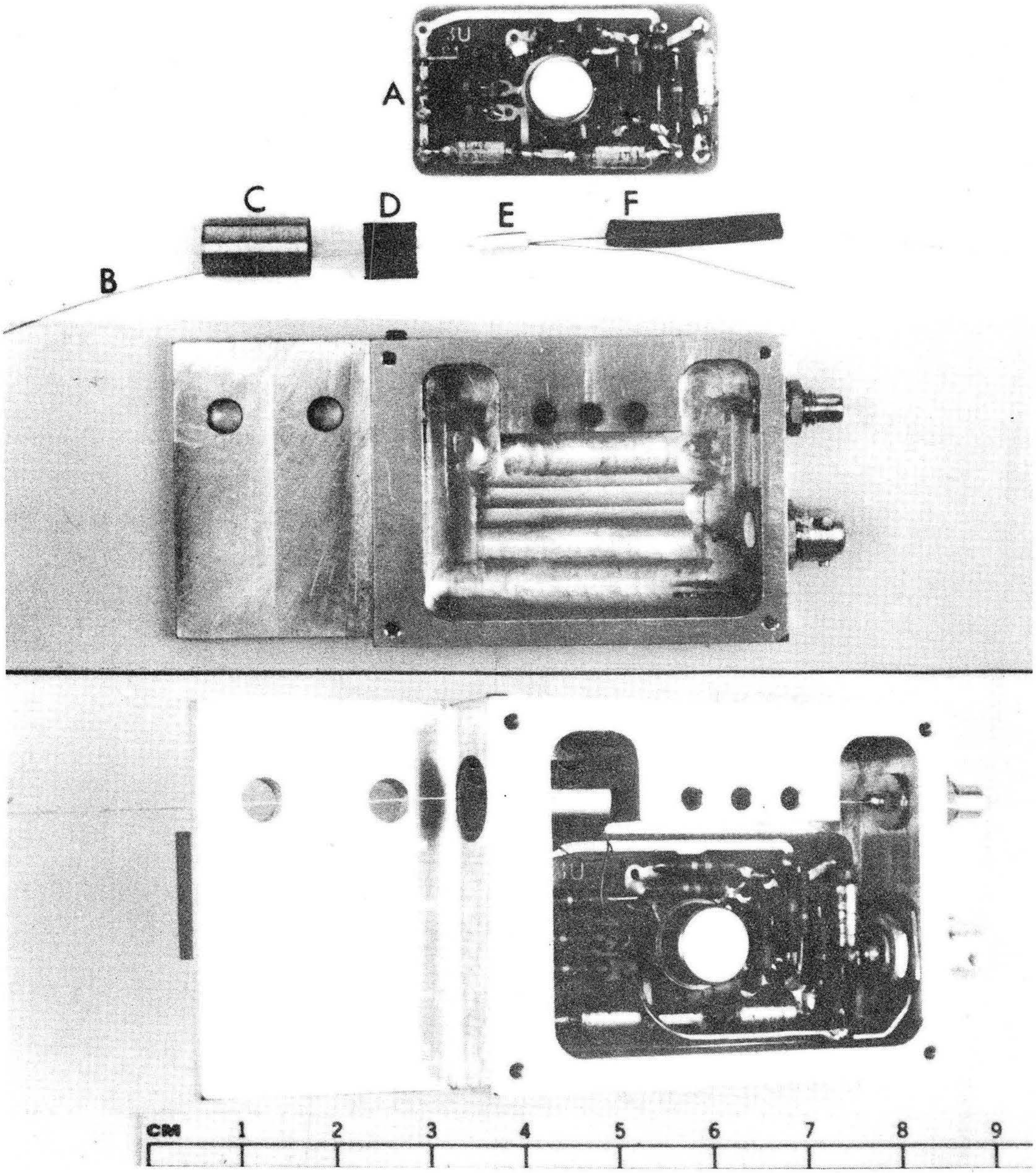


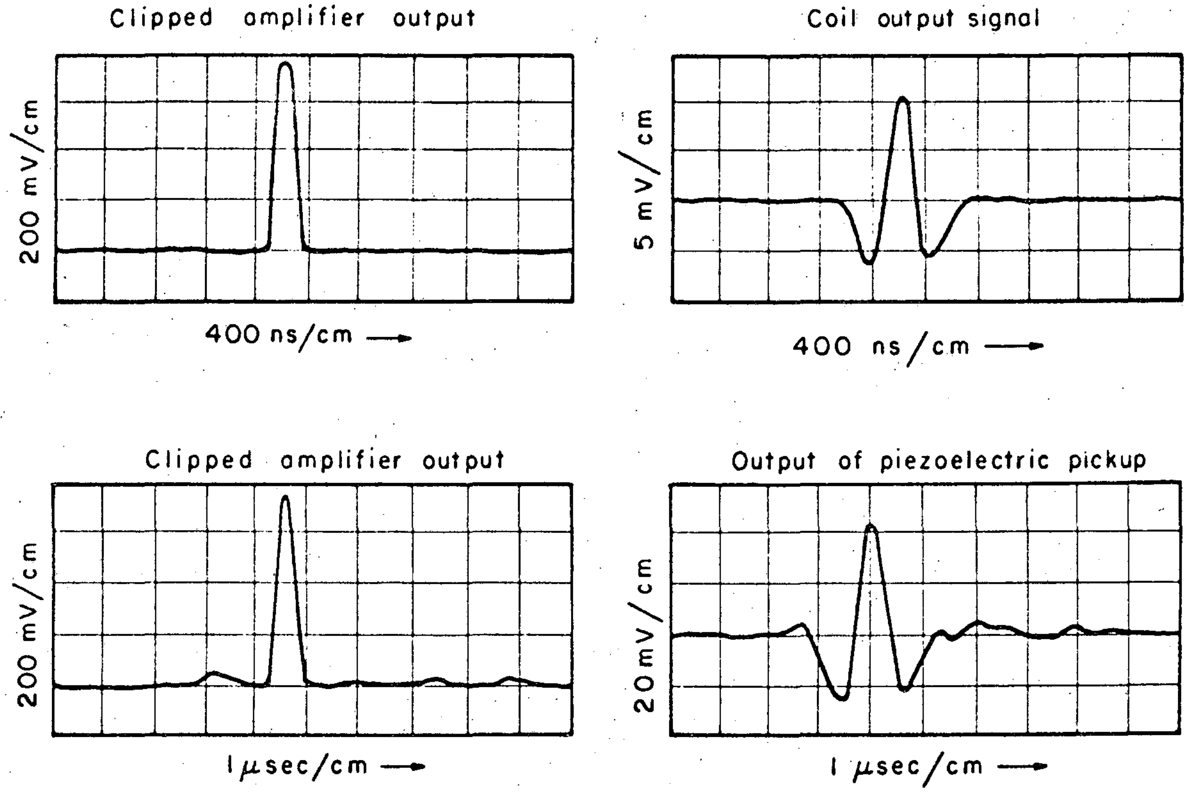
MUB-9646

Fig. 5



ZN-5404

Fig. 6



MUB-9650

Fig. 7

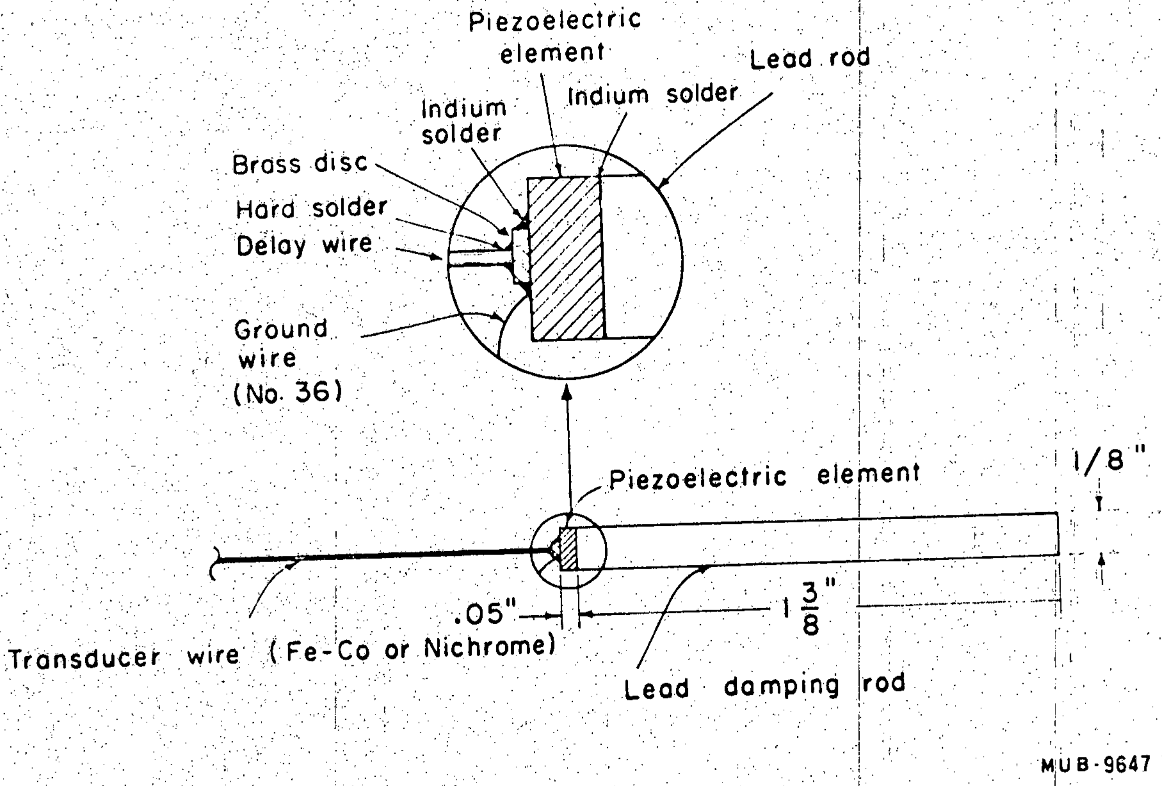
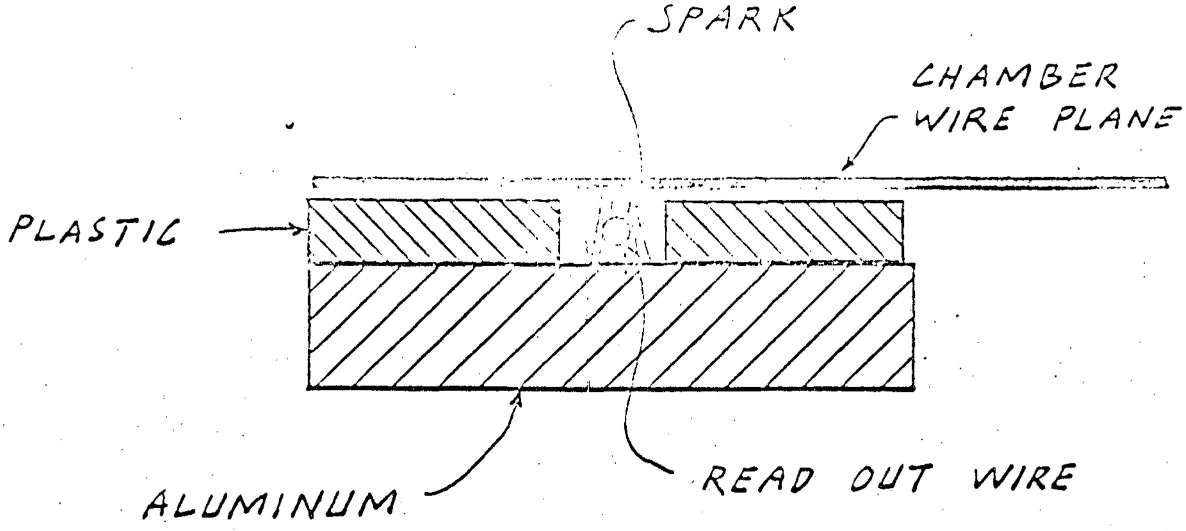
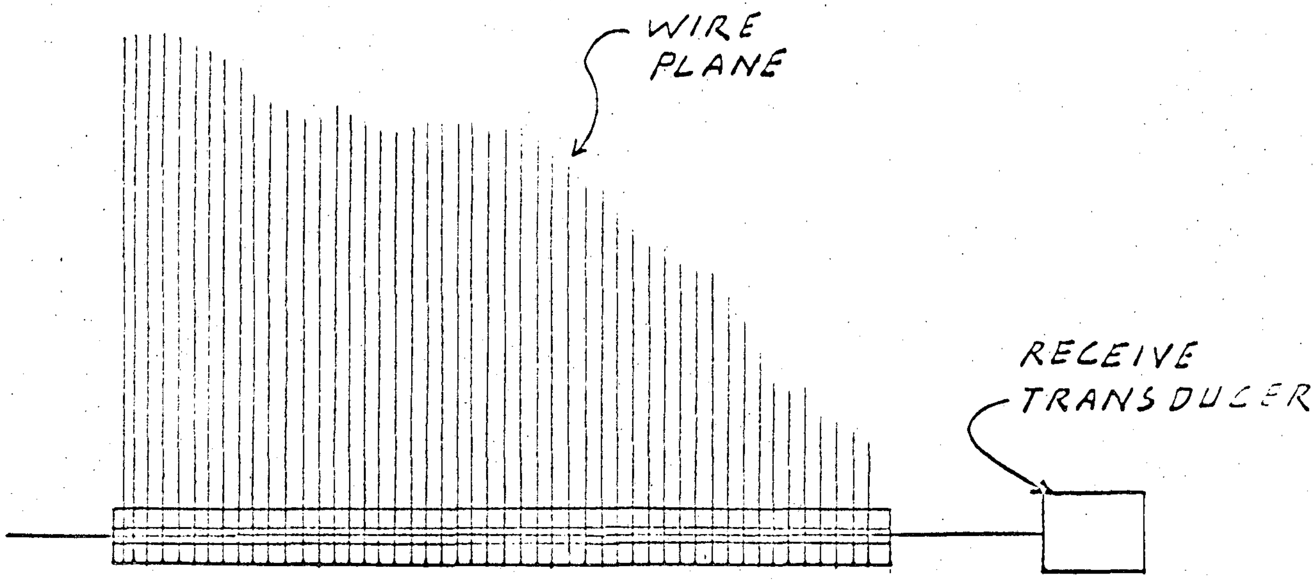

Piezoelectric element
Lead rod
Indium solder
Indium solder
Brass disc
Hard solder
Delay wire
Ground wire (No. 36)
Piezoelectric element
1/8"
.05"
$1\frac{3}{8}$"
Transducer wire (Fe-Co or Nichrome)
Lead damping rod
MUB-9647

Fig. 8

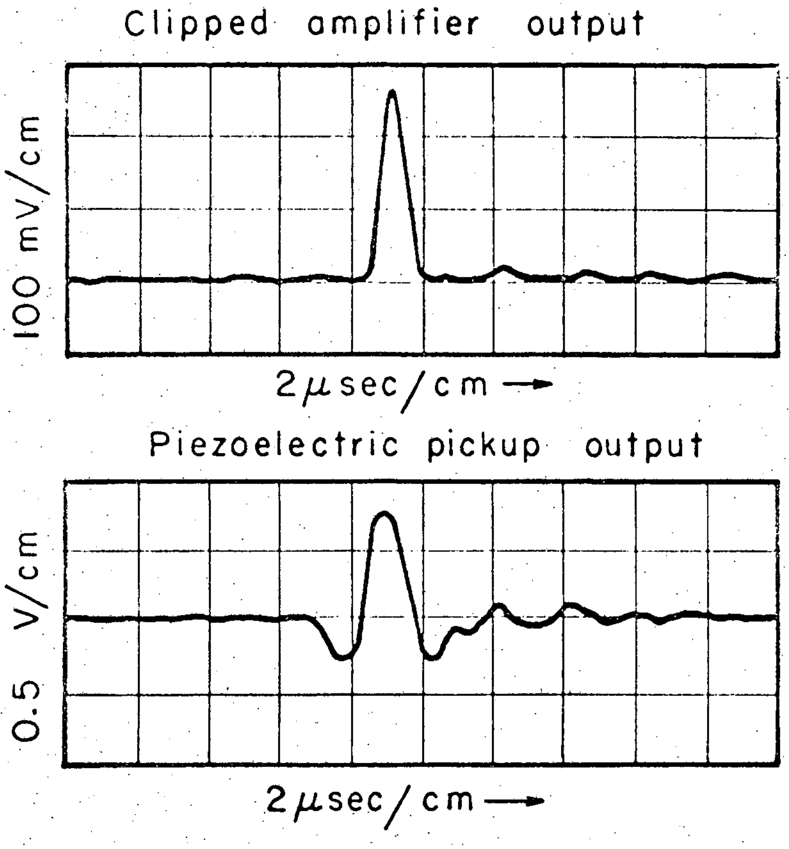


SECTIONAL VIEW



TOP VIEW

Fig. 9



Clipped amplifier output

Piezoelectric pickup output

Fig. 10

MUB-9648